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AIRBORNE CARBON-14 ACTIVITIES IN THE WEST VAULT OF THE UNIT 1 REACTOR AT PICKERING NGS

Report No 85-248-K

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ABSTRACT

A large sampling and analysis program has been carried out to measure the airborne carbon-14 activities in the west vault during shock heating of four fuel channels in Pickering NGS Unit 1. Particulate carbon-14 activities varied from 0.02 to 2.9 $\mu Ci/m^3$, depending on the sampling location and the fuel channel undergoing shock heating. By contrast, the gaseous carbon-14 activities were relatively constant for all samples, ranging from 1.6 to 5.2 $\mu Ci/m^3$. Greater than 98% of this activity was found to be inorganic, probably from $^{14}CO_2$. Tritium was also found in the gaseous samples at an average concentration about seven times higher than the carbon-14 activity.

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EXECUTIVE SUMMARY

AIRBORNE CARBON-14 ACTIVITIES IN THE WEST VAULT OF THE UNIT 1 REACTOR AT PICKERING NGS

K.E. Curtis
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A large sampling program has been carried out in the west vault of Pickering NGS Unit 1 to collect airborne samples during the shock heating of four fuel channels. These samples were required to investigate the dosimetry requirements and the nature of the contamination from a low energy beta emitting particulate material that was discovered during the Large Scale Fuel Channel Replacement Project on both Units 1 and 2. The study of the physical and chemical properties of the material is continuing but the airborne carbon-14 activities in both the particulate and gaseous phases have been determined and are reported here. This report is also intended to serve as the reference document on the sampling schedule and procedures and for sample identification for subsequent work.

Particulate carbon-14 activities varied from 0.02 to 2.9 $\mu Ci/m^3$, depending on the sampling location and the fuel channel undergoing shock heating. By contrast, the gaseous carbon-14 activities were relatively constant between 1.6 to 5.2 $\mu Ci/m^3$. Greater than 98% of this was found to be inorganic, probably from $^{14}CO_2$. Tritium was also found in the gaseous samples at an average activity about seven times that of the carbon-14.

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To Mr. F.J. Kee
Director of Research

AIRBORNE CARBON-14 ACTIVITIES IN THE WEST VAULT OF THE UNIT 1 REACTOR AT PICKERING NGS

1.0 INTRODUCTION

The discovery of contamination by low energy beta emitting particulate material during the Large Scale Fuel Channel Replacement Project on Units 1 and 2 at Pickering NGS has already been thoroughly documented, most recently by Guest/1/ and Greening/2/. Following some preliminary radioanalytical investigations of swipe and personal air sampler (PAS) samples that showed the material to contain high activities of carbon-14, a major sampling and analysis program was initiated. This program was carried out in conjunction with personnel from the Safety Services Department whose main concerns were related to the health physics aspects of the airborne material (performance of various filter materials and PAS systems, particle size distribution and collection of samples for animal studies). The Chemical Research Department sampling trains were designed to give information on the distribution of the carbon-14 activity between the particulate and gaseous phases, to determine concentration gradients between the reactor face and the floor of the vault during shock heating and to collect relatively large samples for studying the physical and chemical properties of the airborne particulate material. The results of the Safety Services Department studies have been reported by Eisner and Stephenson/3/, and the following describes the data obtained by the Chemical Research Department during the sampling program in the west vault of Pickering NGS Unit 1. This report is also intended to serve as the reference document for the sampling schedule and procedures and for sample identification to be used in subsequent documents.

2.0 EXPERIMENTAL

2.1 Sampling Schedule

Four fuel channels were subjected to shock heating treatment to generate airborne carbon-14 in the west vault of Pickering NGS Unit 1.

Full details of the four sampling runs have been documented previously/1,3/ and are described in Table AI of the Appendix to this report. In summary, shock heating of fuel channels H8 and H17 proceeded as expected with the opening of the rolled joint occurring in the fifth and sixth heating cycles, respectively. Fuel channel G7 was anomalous in that no indication of the rolled joint having opened was obtained until the final (eleventh) cycle. The shock heating probe failed on the fourth cycle for fuel channel H9 (first power cycle) and the procedure was terminated with no opening of the rolled joint.

2.2 Sampling Systems

Again, details of the various sampling systems used appear in previous documentation/1,3/ and are fully described in Table AII of the Appendix to this report. Although seventeen samples are identified for each sampling run not all were run each test. Some were collected exclusively for particle size studies (samples 4, 8, 9, 10, 14 and 17) while several were run for other Safety Services Department health physics studies (samples 12, 13, 15 and 16). This report is concerned mainly with the results from the sampling trains that included a particulate filter plus a bubbler system for collecting gaseous samples (samples 1, 5 and 6) and the two high volume Radeco samples (samples 2 and 3) located at the west reactor face and on the rolling shield at the floor level of the west vault.

2.3 Sample Analysis

2.3.1 Particulate Samples

Each of the samples collected on the various filters were first counted for gross beta activity in a Nuclear Enterprises shielded beta/gamma counter located in the Safety Services Department trailer at Pickering NGS/3/. Most of these samples were then transferred to the Research Division and recounted using an Eberline E-140 end window geiger counter calibrated at two detector geometries. The calibrations were carried out by selecting six of the filters, making several measurements of their gross beta count rate and then burning the filters in a Packard Model 306 sample oxidizer. The carbon-14 activity for each filter was then determined by liquid scintillation counting with a Packard Model 300CD system.

In addition, each filter was gamma scanned using a germanium detector coupled with an EG&G Ortec Model 7052 Data Acquisition and Analysis System.

2.3.2 Gaseous Samples

Immediately following a test run, the contents of each bubbler from sampling trains 1,5 and 6 were washed into separate volumetric flasks and diluted to volume with deionized water. Final volumes were 250 mL for the large bubblers originally containing 200 mL of the 0.5 mol/L sodium hydroxide solution and 100 mL for the small bubblers containing 50 mL of the caustic solution.

At the Research Division laboratories, the pH of each solution was first measured to check for possible exhaustion of the sodium hydroxide solution by the large volumes of ambient carbon dioxide passed through the sampling trains. Aliquots of the samples were then taken and their tritium and carbon-14 activities determined by liquid scintillation counting on the Packard Model 300CD system. Considerable effort was required to overcome the matrix effects of these samples in what is normally considered a relatively simple and routine measurement.

Each sample was then subjected to a carbon-14 distillation procedure/4/ designed to distinguish between inorganic (carbonate, bicarbonate) and organic (oxidizable by silver catalyzed persulfate oxidation) carbon-14 activity. In most cases it was necessary to combine the contents of at least two bubblers from a sample train to obtain a measurable activity by the persulfate oxidation, after the inorganic fraction had been distilled off.

Finally, one of the carbon cartridges from the Radeco high volume samplers (sample H8-2) has been examined. A 200 mg portion was burnt in the Packard Model 306 sample oxidizer and the resulting carbon-14 activity measured by liquid scintillation counting. In addition, a 500 mg portion was subjected to distillation from acidic medium in attempt to determine the nature of the carbon-14 trapped on it. Further studies on this and other carbon cartridge samples are continuing.

3.0 RESULTS AND DISCUSSION

3.1 Calibration of an Eberline E-140 End Window Geiger Counter for Gross Beta Measurements

After gamma counting each filter, several were selected for gross beta calibration measurements as described in

Section 2.3.1. The results of these measurements are shown in Table 1.

TABLE I

Calibration of An Eberline E-140 End Window Geiger
For Gross Beta Counting Of Samples Collected On Filters

Sample No	Total Carbon-14 Activity (dpm)	Count Rate (cpm)		Efficiency	
		Position 1	Position 2	Position 1	Position 2
H8-5	263 400	5010 ± 250	130 ± 30	0.0190	0.000494
H8-12	27 630	430 ± 90	-	0.0156	-
H8-13	48 220	940 ± 50	-	0.0195	-
G7-5	14 500	300 ± 30	-	0.0207	-
H9-11	243 100	4500 ± 700	110 ± 10	0.0185	0.000452
H9-12	67 940	1570 ± 300	-	0.0231	-
			Average	0.0194	0.000473
			Estimated Error	±20%	±20%

Counting efficiencies of 1.94% and 0.047% were obtained at distances of 1.5 cm and 8 cm, respectively, above the surface of the filters. Due to the inherent instability of the readings given by the geiger counter, the uncertainty in these and subsequent measurements has been estimated to be ±20%.

3.2 Gross Beta and Gamma Activities in Airborne Particulate Samples

The results of all the gross beta and gamma activities measured at the Research Division are given in Table AIII in the Appendix.

Included with these results are the airborne concentrations calculated from the activities found and the volumes of air sampled. For samples 12 to 16, these values are considered less reliable than for the other samples because of large uncertainties in the actual volume of air sampled through each filter.

Generally, about half of the measured total gamma activity was found to be due to cobalt-60, with cesium-137, ruthenium-106, antimony-125 and other fission and activation products normally associated with reactor crud accounting for the remainder.

It is of interest to note that an excellent agreement was obtained between the gross beta measurements made by the Safety Services Department (SSD) and the Chemical Research Department (CRD) for filters that contained less than 3 μCi of carbon-14. Above this level, the SSD values were lower than the corresponding CRD results and this trend worsened as the carbon-14 activity increased. This is thought to be due to the excessive dead times associated with the SSD counting equipment for highly active samples, being greater than 50% for observed count rates greater than 100,000 cpm. The use of a second counting geometry at 8 cm above the sample surface for the more active samples undoubtedly minimized this problem during the CRD measurements.

A summary of the pertinent airborne concentrations obtained during the sampling program appears in Table II. Although there is some variability in the data, the following trends are quite clear:

1. Gross beta activities were consistently found in considerable excess of the corresponding total gamma activities, ranging from a 35 fold excess for G7 samples to about 2000 for the H9 test run. In fact, the H9 samples had essentially no gamma activity which suggests that they could be almost pure carbon-14 bearing material.

2. Generally, both the gross beta and total gamma activities in samples collected on the work table at the reactor face were in excess of those of samples collected at the floor level, on the rolling shield. This excess was highest for the H8 samples and was more pronounced for gamma activities than for the corresponding beta activities.

3. All of the trends in the data indicate that the carbonaceous material is more easily dispersed into the air than the heavier crud particles containing the gamma activity. These trends include:

   (i) the greater excess of gross beta activity over total gamma activity in samples collected on the rolling shield versus those from the work table

   (ii) the more pronounced excess of gamma activity collected at the reactor face versus the rolling shield, compared to the excess of gross beta in the same samples, and

TABLE II

Gross Beta and Gamma Activities in Airborne Particulate Material During Pickering NGS Unit 1 Shock Heating

Fuel Channel No	Sample Location	Sample No	Gross Beta Activity (nCi/m^3)	Total Gamma Activity (nCi/m^3)
H8	Work Table	1	2900	14
		2	2300	6.9
H8	Rolling Shield	3	210	0.34
		5	250	0.63
		6	210	0.54
H17	Work Table	1	2500	31
		2	1400	9
		11	1500	6.1
H17	Rolling Shield	3	1000	2
		5	1100	2.7
		6	810	0.67
		7	910	2.3
G7	Work Table	1	49	1.5
		2	41	1.0
G7	Rolling Shield	3	32	0.65
		5	9	0.32
		17	21	0.73
H9	Work Table	1	240	0.14
		11	280	<0.01
H9	Rolling Shield	3	160	<0.01
		5	150	<0.01

(iii) the higher gamma activities found in samples from sample train 1 compared to those from sample trains 2 and 11, all collected on the work table. The inlet to sample train 1 was located directly in front of the outlet of the fuel channel being shock heated, at a distance of about 0.3 m, while sample trains 2 and 11 were located about 1 m from the fuel channel and about 0.5 m below it. Although the

gross beta activities showed the same trend, it was much less pronounced. In fact, it was not observed at all during the H9 test run in which the rolled joint did not open, suggesting that the material sampled at that time was probably airborne due to some process other than the shock heating treatment.

In summary, these results show that relatively high concentrations of carbon-14 bearing particulate material were found in the west vault air of Pickering NGS Unit 1 during shock heating of four different fuel channels. The airborne concentrations varied widely from fuel channel to fuel channel but the maximum permissible concentration in air (MPCa) of 10 nCi/m^3 was exceeded in each case.

3.3 Gaseous Carbon-14 and Tritium Activities

Sampling trains 1, 5 and 6 were designed to collect airborne carbon-14 after the sample had first passed through a particulate filter. These trains consisted of either 3 or 4 bubblers connected in series, each containing 0.5 mol/L sodium hydroxide solution for trapping both $^{14}CO_2$ and $^{12}CO_2$. Airborne tritium was also collected by these sampling trains. In addition, sampling systems 2 and 3 consisted of high volume Radeco samplers containing a particulate filter backed-up by a cartridge containing carbon impregnated with triethylenediamine (TEDA). Although these cartridges are designed for trapping radioiodine, they should also be useful for the collection of any gaseous organic carbon-14 species in the samples.

3.3.1 Results of Analyses of Bubbler Solutions

3.3.1.1 pH of Solution

The pH of each bubbler solution was measured to determine if its alkalinity had been exhausted during sample collection. Generally, all solutions were found to have a pH of between 12.6 to 12.9 (exceptions were some bubblers from sample trains that were noted to "suck-back" during the start or finish of sampling but were still diluted to volume with water). For the high volume sample train 1 (20 L/min) this pH range represents between 10 to 15% of the initial alkalinity present in each bubbler, with the first of the four bubblers having least left. The corresponding figures for the low volume trains 5 and 6 (2 L/min) were between 20 to 25%. No solution was found with its alkalinity, and hence its CO_2 trapping capacity, exhausted.

3.3.1.2 Carbon-14 and Tritium Activities

The results of the carbon-14 and tritium determinations for each bubbler solution are given in Table AIV of the Appendix. Airborne concentrations have been calculated from these reported activities and are discussed in Section 3.3.1.3. Other information of importance include:

(a) Sample Collection Patterns

The collection patterns reported for the samples are important because they give an indication of the success of the sampling procedure. Generally, greater than 90% of a substance of interest will be found in the first two bubblers of a 3 or 4 bubbler system if that substance has been successfully collected by the sampling train. This was achieved for tritium in all the sample trains used, with an average of 77% being caught in the first bubbler and 17% in the second (the results for sample H8-5 have been excluded since cross-contamination occurred from "suck-back" at the completion of sample collection). Similar results were obtained for the low volume samplers 5 and 6 for carbon-14 with average collections of 67% and 24% for the first and second bubblers, respectively. However, the high volume sample train 1 performed poorly with an average of only 61% of the total carbon-14 being trapped in the first two bubblers. Care is required in interpreting these results because sample collection was most likely less than quantitative.

(b) Inorganic and Organic Carbon-14 Fractions

Several of the samples were selected for analysis by a distillation procedure designed to distinguish between inorganic (carbonate, bicarbonate) and organic (oxidizable) carbon-14. An average of 98% of the total carbon-14 per sample was found to be inorganic and this was not found to be dependent on the location of the sample collection.

(c) Sample Train No 6 Results

Sample train 6 was designed to distinguish in situ between $^{14}CO_2$ and ^{14}CO plus oxidizable organic carbon-14 species. Unfortunately "suck-back" occurred both times this train was used and the results must be viewed cautiously. However, for sample H17-6 this "suck-back" was minimal and occurred before the sampling began, leaving sufficient sodium hydroxide solution in all four bubblers for sample collection. These results show that virtually no tritium passed through the type "N" respirator canister, designed

to remove water vapour, and that only 2% of the carbon-14 was found in the two bubblers following the cannister. This result is consistent with the fraction of the carbon-14 found to be organic (oxidizable) by the distillation procedure. Unless the solution that was "sucked-back" at the start of the test penetrated the type "N" canister to such an extent to poison the layer of oxidizing material, there is no reason to suspect that run H17-6 was not successfully carried out.

3.3.1.3 Airborne Concentrations of Gaseous Carbon-14 and Tritium

Airborne concentrations calculated from the activity data in Table AIV and the volumes of air sampled are given in Table III. The average tritium concentration during all four test runs was 21 $\mu Ci/m^3$, about twice the MPCa of 10 $\mu Ci/m^3$, and was on average a factor of 7 higher than the corresponding carbon-14 concentration.

TABLE III

Airborne Concentrations of Gaseous Carbon-14 and Tritium During Pickering NGS Unit 1 Shock Heating

Fuel Channel No	Sample Location	Sample No	Carbon-14 Activity ($\mu Ci/m^3$)	Tritium Activity ($\mu Ci/m^3$)
H8	Work Table	1	2.6	25
H8	Rolling Shield	5	4.8	38
		6	4.6	26
H17	Work Table	1	2.3	15
H17	Rolling Shield	5	5.2	22
		6	4.3	16
G7	Work Table	1	1.6	15
G7	Rolling Shield	5	2.4	13
H9	Work Table	1	1.8	21
H9	Rolling Shield	5	1.9	15

Although there is some variability in the gaseous carbon-14 concentrations, they are much more constant from test run to test run than were the corresponding particulate carbon-14 concentrations (see Section 3.2 and Table II). This suggests that, unlike the particulate carbon-14, a source other than the shock heating process could be responsible for airborne gaseous carbon-14.

The average gaseous carbon-14 activity, most of which was trapped as $^{14}CO_2$, was found to be 3.2 $\mu Ci/m^3$, far below the MPCa of 100 $\mu Ci/m^3$. As suspected from the discussion of collection patterns in Section 3.3.1.2(a), sample train 1 seems to have underestimated the gaseous carbon-14 concentrations in all test runs by about 40%. Obviously the flow rate of 20 L/min was too high to allow sufficient contact time for carbon-14 removal by the four bubbler system. Added to this was the physical carry-over of solution from bubbler to bubbler (determined in some samples by measuring the volume remaining in each bubbler) at this flow rate.

3.3.2 Preliminary Analysis of One Carbon Cartridge

As described in Section 2.3.2, the TEDA impregnated carbon cartridge from sample train H8-2 has been examined for carbon-14 content. Based on these preliminary results, a total carbon-14 activity of 0.10 $\mu Ci/m^3$ was obtained. Of this, only about 30% was found to be inorganic, or at least volatile in boiling acidic solution. If the average total gaseous carbon-14 activity for test run H8 is taken as 4.7 $\mu Ci/m^3$, then the carbon-14 trapped by the carbon cartridge represents 2% of that total, again in agreement with the data from the distillation experiments and from sample run H17-6 (see Sections 3.3.1.2(b) and 3.3.1.2(c), respectively). Further work to identify the carbon-14 species with this and other carbon cartridge samples is continuing.

4.0 SUMMARY AND CONCLUSIONS

4.1 The average airborne carbon-14 concentrations on the west vault rolling shield during shock heating of four fuel channels in Pickering NGs Unit 1 are given in Table IV.

TABLE IV

Average Airborne Carbon-14 Concentrations During Pickering NGS Unit 1 Shock Heating

Fuel Channel No	Particulate Carbon-14 Activity ($\mu Ci/m^3$)	Gaseous Carbon-14 Activities	
		Inorganic ($\mu Ci/m^3$)	Organic ($\mu Ci/m^3$)
H8	0.22	4.6	0.09
H17	0.96	4.8	0.08
G7	0.02	2.4	0.07
H9	0.16	1.9	0.04

These data show that the particulate concentrations are quite variable from fuel channel to fuel channel whereas the gaseous carbon-14 is relatively constant. On average, greater than 98% of the gaseous carbon-14 was found to be inorganic, most likely from $^{14}CO_2$.

4.2 Generally, the particulate samples collected also contained gamma activity but at much lower concentrations than the corresponding carbon-14 activities. The gamma emitting radioisotopes identified were typical fission and corrosion products normally associated with reactor crud.

4.3 Tritium was also found in the gaseous samples at concentrations that were, on average, a factor of 7 higher than the corresponding gaseous carbon-14 concentrations.

4.4 Particulate samples collected at the reactor face near the outlet of the fuel channel undergoing shock heating generally contained higher activities of carbon-14 and gamma emitters than corresponding samples collected at floor level, on the rolling shield. This was not found to be true for the gaseous carbon-14

and tritium samples, suggesting that a source other than the shock heating process could be responsible for their presence in the west vault air.

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2. Greening, F.R., Research Division Report No 85-202-K.

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4. Curtis, K.E., Research Division Report No 81-407-K.

APPENDIX

Tables of Information and Data

TABLE AI

Sampling Schedule During Fuel Channel Shock Heating at Pickering NGS Unit 1

Date and Fuel Channel No	Comments
May 25, 1985 H8	Shock heating commenced at 1130 h, starting on the fifth cycle. The first 4 cycles had been carried out several weeks earlier. A vaneometer located at the outlet of the channel indicated that the rolled joint opened during this first cycle. The final (eleventh) cycle was completed at 1345 h. The sampling systems were run from 0530 h to 1530 h.
May 26, 1985 H17	Shock heating commenced at 1315 h and was completed by 1730 h. The vaneometer indicated opening of the rolled joint during the sixth cycle (third power cycle). The sampling systems were run from 1210 h to 1900 h.
May 28, 1985 G7	Shock heating commenced at 0315 h and was completed by 0730 h. No indication of the rolled joint having opened was given by the vaneometer until the final cycle, and even then this indication was weak with only a very slight movement of vaneometer needle. The sampling systems were run from 0245 h to 0915 h.
May 29, 1985	Shock heating commenced at 0230 h but was terminated at 0400 h due to the failure of the heating probe during the fourth (first power) cycle. No indication of opening of the rolled joint was given by the vaneometer. The sampling systems were run from 0200 h to 0545 h.

TABLE AII

Identification of Samples Collected in the West Vault of Pickering NGS Unit 1 Reactor Building During Shock Heating of Fuel Channels H8, H17, G7 and H9

Sample*	Sampling System and Location of Sample
XX-1	High volume (20 L/min) sampler consisting of either a 0.45 µm Millipore or silver membrane filter followed by two bubblers and then two impingers, each containing 200 mL of 0.5 mol/L NaOH solution and cooled in an ice bath. Located on the work table of the reactor face with the sample inlet directly in front of the fuel channel outlet.
XX-2	High volume (≈100 L/min) Radeco sampler fitted with a GFA/E glass fiber filter and a cartridge containing TEDA impregnated carbon. Run on the work table.
XX-3	As in #2, but run on the west vault rolling shield.
XX-4	Andersen cascade impactor run on the rolling shield.
XX-5	Low volume (2 L/min) sample consisting of a 0.8 µm Millipore filter followed by either three or four bubblers containing 50 mL of 0.5 mol/L NaOH solution, run on the rolling shield.
XX-6	Similar to #5 except that a type "N" respirator canister was positioned between the second and third bubblers to oxidize CO and hydrocarbon to CO_2.
XX-7	A 0.4 µm Nuclepore filter attached to the inlet of a small metal bellows pump on the rolling shield. Run at 3 L/min to collect material to be used for rat inhalation studies.
XX-8	Low volume (2 L/min) Stephenson lung model sampler run on the rolling shield.

TABLE AII (Cont'd)

Identification of Samples Collected in the West Vault of Pickering NGS Unit 1 Reactor Building During Shock Heating of Fuel Channels H8, H17, G7 and H9

Sample*	Sampling System and Location of Sample
XX-9	A personal air sample (PAS) containing a 0.4 µm Nuclepore filter. Run on the work table, to be used for particle sizing by scanning electron microscopy (SEM).
XX-10	As in #9, run on the rolling shield.
XX-11	A PAS containing a 0.8 µm Millipore filter, run on the work table.
XX-12 to 16	A selection of filters connected in parallel to a single vacuum pump situated on the rolling shield: #12, a 0.8µm Millipore filter followed by #12B, a GFA glass fiber filter, connected in series. #13, a 0.8 µm Millipore filter. #14, a 0.4 µm Nuclepore filter. #15, three GFA glass fiber filters in series. #16, either a GFA glass fiber or 0.4 µm Nuclepore filter.
XX-17	High volume (30 L/min) Stephenson lung model sampler run on the rolling shield.

* Note: XX refers to the fuel channel number; eg Sample H8-1 or H17-3.

TABLE AIII

Gross Beta and Total Gamma Activities of Airborne Particulate Samples Collected During Pickering NGS Unit 1 Shock Heating

Sample No	Gross Beta Activity (nCi)	Airborne Gross Beta Activity (nCi/m^3)	Total Gamma Activity (nCi)	Airborne Total Gamma Activity (nCi/m^3)
H8- 1	14,000	2,900	67	14
2	51,000	2,300	150	6.9
3	4,700	210	7.4	0.34
5	120	250	0.30	0.63
6	100	210	0.26	0.54
12	12	25	<0.02	-
13	22	46	<0.02	-
14	23	48	<0.02	-
15	58	120	0.07	0.15
H7- 1	16,000	2,500	200	31
2	67,000	1,400	440	9.0
3	50,000	1,000	100	2.0
5	780	1,100	1.8	2.7
6	560	810	0.46	0.67
11	1,000	1,500	4.2	6.1
12	290	420	NM*	-
13	360	520	NM	-
14	600	870	NM	-
17	6,900	920	24	2.3
G7- 1	330	49	10	1.5
2	1,300	41	32	1.0
3	1,000	32	21	0.65
5	6.5	9.0	0.23	0.32
12	4.2	5.8	0.10	0.14
13	3.3	4.5	<0.02	-
15	5.1	7.1	<0.02	-
17	230	21	7.9	0.73
H9- 1	940	240	0.56	0.14
3	2,400	160	0.13	0.01
5	55	150	<0.02	-
11	110	280	<0.02	-
12	31	79	<0.02	-
13	19	51	<0.02	-
15	33	85	<0.02	-

*NM = Not Measured

TABLE AIV

Gaseous Carbon-14 and Tritium Activities in the West Vault Air During Pickering NGS Unit 1 Shock Heating

Sample No	Bubbler No	Tritium Activity µCi	Tritium Activity % of Total	Carbon-14 Activity µCi	Carbon-14 Activity % of Total	Carbon-14 Activity % Organic
H8-1	1	82	70%	4.8	38%	3.3%
	2	24	20%	2.8	23%	
	3	9.7	8%	2.5	20%	
	4	2.5	2%	2.4	19%	
H8-5*	1	6.0	33%	0.62	27%	0.7%
	2+3	12	67%	1.7	73%	
H8-6*	1	12	97%	1.3	60%	not measured
	2	0.3	3%	0.82	38%	
	3	0.01	-	0.02	1%	
	4	<0.01	-	0.02	1%	
H17-1	1	73	76%	5.2	35%	1.2%
	2	17	18%	4.0	27%	
	3	3.8	4%	3.2	21%	
	4	1.8	2%	2.6	17%	
H17-5	1	10	67%	2.2	61%	2.2%
	2	3.8	25%	1.1	30%	
	3	1.2	8%	0.34	9%	
H17-6*	1	9.2	84%	2.5	85%	not measured
	2	1.7	16%	0.39	13%	
	3	0.02	-	0.06	2%	
	4	<0.01	-	0.01	-	
G7-1	1	79	76%	3.9	35%	3.1
	2	23	22%	3.3	29%	
	3	1.3	1%	2.7	24%	
	4	0.9	1%	1.3	12%	
G7-5	1	5.9	65%	1.2	69%	2.8%
	2	1.5	17%	0.25	14%	
	3	0.90	10%	0.21	12%	
	4	0.74	8%	0.08	5%	

TABLE AIV (Cont'd)

Gaseous Carbon-14 and Tritium Activities in the West Vault Air During Pickering NGS Unit 1 Shock Heating

Sample No	Bubbler No	Tritium Activity µCi	Tritium Activity % of Total	Carbon-14 Activity µCi	Carbon-14 Activity % of Total	Carbon-14 Activity % Organic
H9-1	1	70	84%	2.3	33%	2.3%
	2	11	13%	1.9	27%	
	3	1.7	2%	1.5	21%	
	4	0.7	1%	1.3	19%	
H9-5	1	4.0	70%	0.46	60%	not measured
	2	1.4	25%	0.20	26%	
	3	0.18	3%	0.08	11%	
	4	0.01	2%	0.02	3%	

* Note: Samples H8-5, H8-6 and H17-6 "sucked-back" either at the start or finish of the sampling period, causing cross contamination between individual bubblers.